A CHART OF THE RECENT TECTONICS OF THE ARCTIC

by

A.P. PUMINOV

Translated by

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DEFENCE RESEARCH BOARD

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(Presented by A.L. Yanshin, Member of the Academy, 6 March, 1967)

Translated from
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In 1966, for the first time, a chart of the *recent* tectonics of the Arctic has been compiled, on a scale of 1 : 5,000,000, by the Institute of Arctic Geology.* The compilers of the chart comprise over fifty co-workers from the Institute of Arctic Geology, the All-Union Geological Institute, the All-Union Petroleum Institute, the All-Union Institute of Prospecting Geophysics, the All-Union Aero-geological Combine, the Siberian Institute of Geology, Geophysics and Mineral Resources, the Second Hydrogeological Directorate, the Institute of Terrestrial Physics, USSR Academy of Sciences, the Institute of Volcanology, Siberian Division of the USSR Academy of Sciences, the Institute of the Earth's Crust, Siberian Division of the USSR Academy of Sciences, the Institute of Geology of the Yakutian Branch, Siberian Division of the USSR Academy of Sciences, Leningrad National University, Moscow National University, and the Institute of Marine Fisheries and Oceanography.

In this chart of the recent tectonics of the Arctic and Subarctic there are four special schematic insert-charts, as follows:

1) chart of relationships of recent and ancient geostructural regions;

2) geomorphological chart;

3) chart of types of terrestrial crust;

4) distribution chart of earthquake epicenters.

This is the first chart to show the recent structural forms of continents and ocean floors on the basis of the same unified principles of defining geostructural regions. Consequently, in the compilation of the chart, newly developed methods of showing the recent tectonic structures of the continental shelf and ocean basins have been employed for the first time.

On the basis of trend and intensity of recent tectonic movements the chart defines *continental platforms*, *oceanic platforms (thalassocratons)*, *orogenic regions* and *geosynclinal regions*.

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* Editorial collegium for the chart: I.P. Atlasov, A.A. Bogdanov, A.F. Grachev (Deputy Chief Editor), R.M. Demeniçkaya (Deputy Chief Editor), V.D. Dibner, B. Kh. Yegiazarov, A.M. Karasik, M.T. Kiriushina (Deputy Chief Editor), Yu. N. Kulakov, F.G. Markov, N.I. Nikolayev, Ya.I. Pol'kin, A.P. Puminov (Chief Editor), I.A. Rezanov, B.S. Romanovich, B.V. Tkachenko, G.B. Udinçev, S.S. Shul'ç. Authors of the explanatory text: A.P. Puminov, A.F. Grachev, A.M. Karasik. Cartographic Group: T.P. Vlasova, M.A. Isayeva, N.D. Shurgayeva.

Continental platforms are relatively stable regions with a prevalence of general, low-intensity, long-term rising movements. The continental platforms are subdivided into two groups: *uplifted continental platforms* (the Central Siberian platform et al.), characterized by vertical movements of average amplitude (—200 to +600 m), and *mildly uplifted continental platforms* (the Khatanga River - Central Kara Sea - West Siberia platform et al.), in which the uplifts attain 200-300 m and the subsidences are of 100 m size — rarely 500 m or above. The shields within the uplifted platforms (the Anabar shield, the Baltic shield, et al.) have undergone uplifts of 600-1000 m; it is usual for them to include numerous blocks with mutual dislocations of 200 m or more.

Oceanic platforms [thalassocratons] are relatively stable regions with a predominance of general, long-term subsidences, both of slight amplitude and of considerable amplitude. The thalassocratons are subdivided into "inherited" or relatively stable platforms and newly formed or subsided platforms. The *"inherited"* oceanic platforms (the Nansen platform, the Amundsen platform, et al.) are characterized by subsidences of up to 1 km (oceanic cratonic plates) and by the development, on the thalassocratonic background, of large structural rises (the Obruchev rise et al.) as much as 0.5 to 1 km high. These platforms are on crust of oceanic type or, less frequently, of quasi-oceanic [transitional] type. The *newly formed* oceanic platforms (the Okhotsk Sea thalassocraton, the Baffin Bay thalassocraton,* et al.) take the form of non-compensated subsidences of as much as 3 to 4 km depth. Within these platforms there are sub-oceanic mountain ranges (the Shirshov mountains et al.), representing segments which have, in the recent tectonic stage, experienced a relatively smaller subsidence (up to 1 km). The *newly formed oceanic platforms* have a crust of [transitional] quasi-oceanic or quasi-continental type.

Orogenic regions are zones of recent differential movements of various intensities, with prevalence of rising movements. Two types of orogenic region are distinguished: epicratonic and epigeosynclinal.

The regions of *epicratonic* [platform] orogeny are subdivided into sub-regions, continental and oceanic. The sub-regions of *continental* epicratonic orogeny have been defined by their sites (variously aged platforms). They are divided, according to intensity of tectonic processes and amplitude of movements, into three types, namely: regions of strong orogeny (the Baikalian mountains et al.), of moderate orogeny (the Norwegian mountains et al.) and of mild orogeny (the Taimyr mountains et al.), with uplift amplitudes of 3 km, over 2 km, and below 1-1.5 km respectively, and with subsidences of 1-2 km, over 1 km, and over 0.5 km respectively. The sub-regions of *oceanic* epicratonic orogeny are divided into two groups, namely: sub-regions of moderate orogeny (mid-ocean ridges with active volcanism, seismicity and a clear-cut system of rifts), and sub-regions of mild orogeny (the sub-oceanic Lomonosov and Mendelyeyev [Alpha] ridges, which show no signs of volcanism). In these sub-regions the uplift heights are 2.5 to 3 km and 2 km respectively, and the downwarp depths are 0.5 and 1 km respectively.

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* Baffin Bay thalassocraton: See J. Wm. Kerr, A submerged continental remnant beneath the Labrador Sea. Earth and Planetary Science Letters, Vol.2 (1967), 283-289. [Translator].

The regions of *epigeosynclinal* orogeny are represented, in the Arctic, by a group of intensely orogenic zones (uplifts of over 3 km, downbucklings of over 0.5 km). This group includes the Kamchatka region, the Koryak mountain country and the South Alaska mountains; here the general inversion stage of geosynclinal development has been completed, and from the characteristics of recent structure, of volcanism and of crustal structure we can consider them as being in different phases of the mountain building stage of development.

Geosynclinal regions are mobile regions, with sharply differentiated movements and a predominance of subsidences over rises. On the chart, one geosynclinal region is shown, namely the Aleutian. It is divided into two structural zones: an island arc and an oceanic trench. The Aleutian island arc exhibits the large vertical amplitudes typical of recent tectonic movements (—1000 to +600 m or more). In the Aleutian trench the subsidences exceed 300 m. The whole span of the movements in the Aleutian geosyncline during the Pliocence and Quaternary amounts to over 4 km. The terrestrial crust in the geosyncline is heterogeneous, ranging from quasi-continental to quasi-oceanic type.

The continental slope is regarded as a zone of transition from continental to oceanic structures. The continental slope plus the continents and the ocean basins together constitute a structure of higher order as compared with the geostructural regions we have defined. In most cases the continental slope had begun to develop before the recent tectonic stage, but in certain cases (Bering Sea, Baffin Bay and elsewhere) the formation of the continental slope did take place within the recent stage. The crust in the continental slope belongs to the quasi-continental type.

Although on the whole the development of the recent tectonic (relief-forming) movements in the Arctic and Subarctic is assigned to post-Middle-Oligocene times, analysis of the material has led to the identification of two regionally distinct temporal boundaries for the commencement of these movements: namely, a Late Oligocene boundary (in the Atlantic segment of the Arctic) and a Late Pliocene boundary (in the Pacific segment of the Arctic).

The chart of recent Arctic tectonics, in a highly schematized form, is reproduced in Figure 1.

Research Institute
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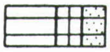
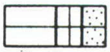
CONTINENTAL PLATFORMS


Uplifted Continental Platforms:-

1 - Barents Sea - Europe platform.
(1a, Baltic shield.
(Cratonic plates: 1b, Baltic; 1c, White Sea - South Barents - Pechora.
(Downwarps: 1d, Bear Island; 1e, Fr. Josef Land - Victoria Island.

2 - Central Siberian platform.
(Shields: 2a, Anabar; 2b, Putoran.
(2c, Aldan basin.

3 - North American platform.
(3a, Canadian shield.
(Downwarps or troughs: 3b Hudson; 3c, Barrow Strait - Lancaster Strait; 3d, M'Clure Strait; 3e, MacLean Strait - Prince Gustaf Adolf Sea; 3f, Amundsen Gulf.
(3g, Mackenzie basin.


Mildly Uplifted Continental Platforms:-

4 - Khatanga River - Central Kara Sea - West Siberia platform.
(4a, Baidaraçkaya depression.

5 - Lower Lena - Chukchee - North Alaska platform.
(Downwarps or troughs: 5a, East Siberia coastal; 5b, Alaska coastal; 5c, Chukchee.
(Shields: 5d, New Siberian Islands; 5e, Wrangel Island.

6 - Shelekhov Strait - Okhotsk Sea platform.

7 - Rockall - Faeroes - Scotland platform.
(Cratonic plates: 7a, Rockall; 7b, Faeroes - Iceland.
(7c, Faeroes - Scotland downwarp.

OCEANIC PLATFORMS --- THALASSOCRATONS


"Inherited" Oceanic Platforms:-

8 - Nansen platform.
(8a, Nansen cratonic plate.

9 - Amundsen platform.
(9a, Amundsen cratonic plate.

10 - Canada Basin - Beaufort Sea cratonic plate.
(Rises: 10a, Chukchee; 10b, Beaufort.

11 - Mackenzie cratonic plate.

12 - Northeast Pacific Ocean cratonic plate.
(Rises: 12a, Obruchev; 12b, Sirius; 12 c, Northeast.

13 - Labrador cratonic plate.
14 - Irminger cratonic plate.
15 - South Iceland cratonic plate.
16 - Greenland cratonic plate.
17 - Norway cratonic plate.
18 - Lofoten cratonic plate.


Newly Formed Oceanic Platforms:-

19 - Okhotsk Sea thalassocraton.

20 - Bering Sea thalassocraton.
(Undersea "mountains": 20a, Shirshov; 20b, Bowers Bank.

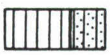
21 - Baffin Bay thalassocraton.

22 - Ireland thalassocraton.

OROGENIC REGIONS

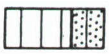

Continental Epicratonic Strongly Rising Mountains.

23 - Baikalian Mountains.
(23a, Baikal and Barguzin depressions.


Continental Epicratonic Moderately Rising Mountains:-

24 - Norwegian mountains.
(24a, Norway monocline.

25 - Verkhoyan - Chukchee - Alaskan mountains.
26 - Greenland and Eastern Canadian mountains.


Continental Epicratonic Mildly Rising Mountains:-

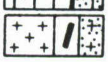
27 - Northern Ural and Nova Zemlia mountains.
(Downwarps: 27a, Nova Zemlia trough; 27b, St. Anna trough.

28 - Taimyr Peninsula and Severnaya Zemlia mountains.
(28a, Voronin Trough; 28b, Vil'kiçki Strait - Laptev Sea trough.

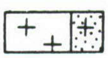
29 - Yeniseian mountains.


Epigeosynclinal Strongly Rising Mountains:-

30 - Kamchatkan mountains.
31 - Koryak and South Alaskan mountains.


Oceanic Epicratonic Moderately Rising Mountains (Mid-ocean Ridges):-

32 - Atlantic ridge.
33 - Arctic ridge (Hakkel's mountains).
(32a and 33a, rifts; 33b, supposed prolongation of rift.


Oceanic Epicratonic Mildly Rising Mountains:-

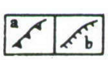
34 - Lomonosov - Mendeleyev undersea ridge system.
(Downwarps: 34a, Makarov; 34b, Toll'.

GEOSYNCLINAL REGIONS


Island Arch and Ocean Trenches:-

35 - Aleutian Islands arc.
(Downwarps: 35a, Near Islands - Commander Islands [channel];
35b, Near Islands - Buldyr Island [channel];
35c, Rat Islands - Andreanov Islands [channel];
35d, Andreanov Islands - Four Mountains Islands [channel].

36 - Aleutian oceanic trench.



Continental Slopes (a - inherited; b - recent).

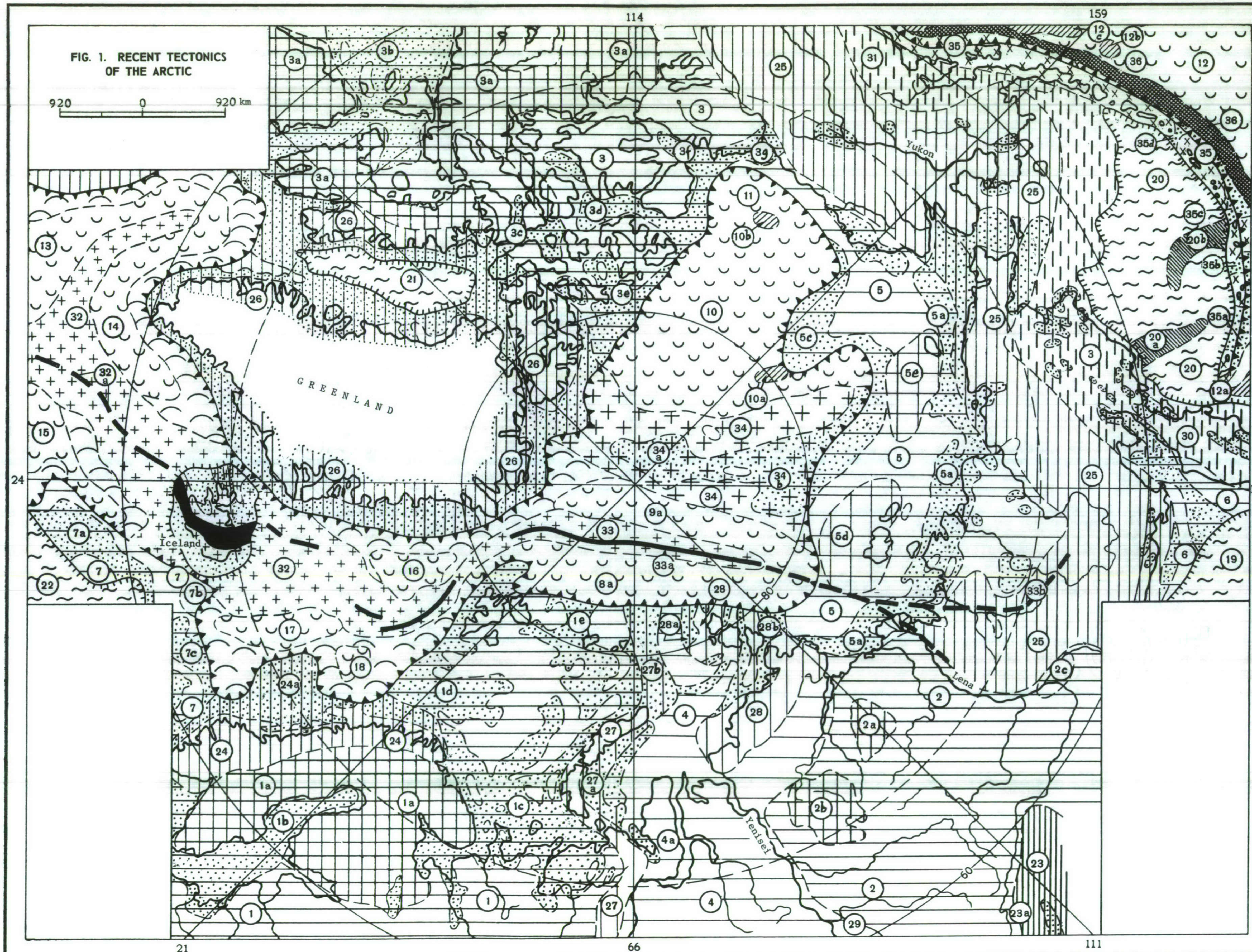


FIG. 1. RECENT TECTONICS OF THE ARCTIC

COMMENTS OF THE TRANSLATOR

E.R. Hope

The present chart of recent Arctic tectonics may be compared with the general tectonic chart of the Arctic previously published (ref. [1]) by the same authority, the Institute of Arctic Geology.

The Lomonsov and Mendeleyev (Alpha*) sub-oceanic mountains are shown as a single orogenic feature (no. 34 on the chart), with two large depressions or troughs (34a, 34b) effecting a partial separation into two ridges. The two depressions, it is interesting to note, are represented as continuations of the *Chukchee Trough* (no. 5c), a feature that is shown extending, as a frontal downwarp, along the edge of the *Canada Basin - Beaufort Sea cratonic plate* (no. 10) --- which we may identify with Shatski's Hyperborean Shield (or Platform); see ref. [2], pages 411, 415.

The idea of the Lomonosov and Mendeleyev mountains as a single system --- presumably a folded system --- is interesting. Whether it is correct may perhaps be decided by evidence of a continuation of the orogenic disturbance onto the continental shelves and land masses at either end. The Mendeleyev or Alpha Ridge has been regarded as a horst, lying entirely within the oceanic platform. In contrast to the Lomonosov Ridge, it does not ---so far as the translator knows ---continue into or affect the neighboring masses in any way. (Cf. [2], pages 414-5; [1], page i.)

The nature of the Lomonosov Ridge has not been decided. It is not an intrusive dyke, for it is relatively non-magnetic; it is not a mid-ocean ridge (or at least, not an active mid-ocean ridge), since it is practically aseismic. The character of the Mendeleyev Ridge is even less clear, for less is known about it.

If the European-Arctic Basin** (nos. 8a, 9a*** on the chart) were closed up and its sides brought together, the Lomonosov mountains would be juxtaposed with the edge of the north European continental shelf and its elevations (Spitsbergen, Franz Josef Land and the islands of Severnaya Zemlia). In all probability this was the original position, for the magnetic pattern (Fig. A) of the floor of the European Arctic Basin shows it to be expanding, by formation of new oceanic crust at the central ridge. Successive reversals of the geomagnetic field have laid down successive bands of oppositely magnetized ocean floor material. The Lomonosov Ridge, then, may represent one side of a pre-existing, axially rifted mountain system ([1], page i), or it may be a folding produced by the thrust of the expanding ocean floor.

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* The name Alpha Range was suggested (Hope, [2], page 414) on the basis of apparent U.S. priority in the discovery of this mountain system.

** Now called by the Russians the Nansen-Amundsen Basin (see ref. [3]). In the chart it is shown as two separate basins, the Nansen and the Amundsen, on either side of the central ridge (33a).

*** The numbers 8 and 9 of the key are missing from the chart.

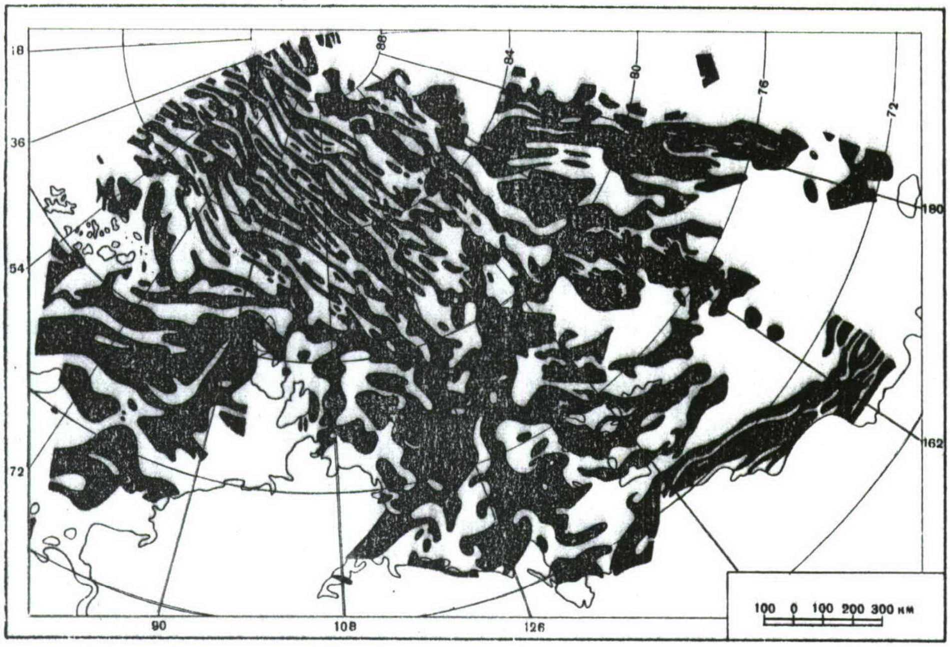

Fig.A. Reproduced from ref.[3]. The original caption reads: Preliminary chart of magnetic anomalies $(\Delta T)_a$ in the Euro-Asiatic sector of the Arctic Ocean, according to aeromagnetic survey data. Black: $(\Delta T)_a > 0$. White: $(\Delta T)_a < 0$. Chart compiled by R. M. Demeniçkaya A. M. Karasik.

Figure A is a brilliant confirmation of Ewing and Heezen's surmise [4] that the Mid-Atlantic ridge might extend through this basin on the European side of the Lomonosov Ridge. This surmise was published in 1959; meanwhile the mountains of the central ridge (no. 33 on the chart) were discovered by Soviet oceanographers ([2], page 423). They were, however, taken to be a fold system, an extension of Hercynian folding from the continent. (This idea has now been definitely abandoned, on the magnetic evidence.)

In the key to the chart, under no. 33, the central ridge is identified as "Hakkel's mountains". That is, the discovery of the central ridge in the European Arctic Basin is attributed to Ya. Ya. Hakkel', the Soviet cartographer who played such an important part in the mapping of the Lomonosov Ridge. (Cf. [2], pp. 410-411.)

As compared with the European Arctic Basin, the floor of the Canada Basin, on the other side of the Lomonosov Range, exhibits a quite different magnetic pattern (Fig. A). The Soviet tectonic charts are evidently maintaining the hypothesis of a platform in this area: a thalassocraton of some undefined type, or even a subsided continental platform (Saks, Belousov). Hence the notion of the platform-edge downwarp or foredeep 5c with its extensions 34a and 34b between the Lomonosov and Mendeleyev Ridges.

The East Siberia coastal trough 5a also is shown with a small seaward extension, departing from the coast at about the 120th meridian east. One might suppose this to be the Sadko Trough (see ref. [2], Fig. 1 and page 418). It does not, however, reach far enough northward.

Not much is known about the Sadko Trough; most charts still fail to show it. The translator is therefore taking this opportunity to present further information that he has been able to glean in the years since the publication of ref. [2]. As will appear from the following translated excerpts, the eastern edge of the Sadko Trough is identified as an abrupt descent of the ocean floor at or near *81°N, 120°E*. The trough therefore, at this latitude, lies somewhat west of the position shown in Fig. 1 of ref. [2]. In fact, it is about on the axial line of the European Arctic Basin, and very likely in line with the central ridge and rift (33a). This is quite interesting in view of Heezen's suggestion [5] that the Sadko Trough could represent the mid-ocean rift cutting into the continental rise.

Excerpt from an article signed by O. Stroganov, Special Correspondent, in the Newspaper Izvestiya, No. 273, November 18th, 1961

When the atomic icebreaker (the Lenin) reached the point *81° 07'N° 119° 55'E*,* Captain B.M. Sokolov gave the order to stop the engines and start a 3-day drift. It was necessary to make some scientific observations. The hydrologists immediately unloaded their winch onto the ice and undertook depth, temperature, salinity and current measurements. The sounding lead, lowered through the well (in the ice), could not reach the ocean bottom. Twice the cable had to be lengthened. Finally the depth was measured — 3400 meters. This meant that the icebreaker had passed the Lomonosov Ridge and was over the Sadko Depression.** The water temperature to the very bottom was below 0° C; only at the 300 - 400 m. level were warm Atlantic streams encountered.

The Last Beacon: Partial translation of a news item from Vodnyi Transport, 30, No.136(4336), Thursday, November 16th, 1961 (page 4)

When the ship (the Lenin) was still at 81 degrees of north latitude and some 500 nautical miles from the pole, the echo sounder in the wheelhouse stopped indicating the depth. For the first few moments, no one could imagine what was up. Ustinov, in charge of electrical navigation, requested Captain Sokolov to stop the engines, in order to get rid of interference caused, as he thought, by the shattered ice. But even after this was done the echo sounder continued to give strange indications.

"It's just packed up". The technician shrugged his shoulders.

But they were wrong to blame the echo sounder like this. Engineer Yurii Konstantinov, taking advantage of the ship's being stopped, decided to try for the bottom by the ordinary method of sounding. Soon he came up on the bridge and announced that the cable of the hydrological winch, run out to its

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* The date is not stated, except that it was a few days prior to the 18th November, 1961.

** The Lenin was therefore proceeding westward.

full length of 3130 meters, had not touched bottom. Now the puzzling behavior of the NEL-5 echo sounder was understandable. It simply was not ranged to "sound through" to such a depth. We were in the region of the deep Sadko Trough.*

The uncertainty did not at all suit the shipboard representatives of the hydrographic service of the Northern Sea Route Authority, I. Gebazankov, D. Selivanov and A. Charistov. They decided to get a sounding at all costs. They spliced another 500 meters onto the cable of the hydrographic winch and started the job all over again from the beginning.

At midnight, fourteen hours after the ship was stopped, the chilled and dog-tired hydrographers, together with Konstantinov who had worked through without relief, reported their results to the bridge. There were 3460 meters of water under the keel. A hydrographic station made by Konstantinov, Churkina and Vilkov a day later showed a depth of 3412 meters. And the lead brought up from the bottom of the ocean a little cone of brown ooze.

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[5] B.C. Heezen. In: Geology of the Arctic. Proc. First Internat. Symposium of Arctic Geology, 1960. University of Toronto Press, 1961, vol.1, p.638.

* Since the Lenin was proceeding westward, the sudden failure of the echo-sounder to indicate depths must have coincided with the ship's passage over the abrupt, eastern wall of the Sadko Trough. (E.R. Hope)